Geologic Resource Evaluation Scoping Summary
Point Reyes National Seashore, California

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this report), a digital geologic map, and a geologic resource evaluation report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRE scoping meeting for Point Reyes National Seashore on September 26–28, 2007. Participants met in a meeting room overlooking Rodeo Lagoon and the Pacific Ocean at Fort Cronkhite, Marin Headlands, Golden Gate National Recreation Area. On September 26, Tim Connors (Geologic Resources Division) facilitated the assessment of map coverage, and Bruce Heise (Geologic Resources Division) led the discussion regarding geologic processes and features. Participants had a separate discussion about coastal and marine features and processes on September 28. During a field trip on September 27, participants traveled into the national seashore. Participants at the meeting included NPS staff from Point Reyes National Seashore, Golden Gate National Recreation Area, San Francisco Bay Area Network, Pacific West Regional Office, Geologic Resources Division, and Washington Office, and cooperators from the Presidio Trust, National Marine Sanctuary, National Oceanographic and Atmospheric Administration, U.S. Geological Survey, California Geological Survey, and Colorado State University (see table 2).

Park and Geologic Setting

The Point Reyes peninsula is a roughly triangular land area in Marin County, California. It projects westward from the valley created by the San Andreas Fault to an apex—Point Reyes—into the Pacific Ocean (Clark et al. 1984). Local activism and federal foresight resulted in the creation of a national seashore at this location (Lage 2004). As early as 1935, the National Park Service had its eye on Point Reyes when it recommended to Congress the purchase of 21,807 ha (53,884 ac) for recreational use. However not until 1956, when threats from development seemed imminent (e.g., Drakes Beach Estates subdivision) did Congress begin seriously considering acquiring this acreage. Negotiations and compromise with many stakeholders finally resulted in President John F. Kennedy signing the bill that authorized the establishment of Point Reyes National Seashore as part of the National Park System on September 13, 1962. Though an important step, Congress did not appropriate enough money to purchase all of this acreage until 1972 when President Nixon authorized the funds. In 1976 citizens and local conservation groups banded together in support of a proposal for a wilderness area within the national seashore. In 1985 Congress designated 10,267 ha (25,370 ac) as the Philip Burton Wilderness, named for the congressman from San Francisco who was responsible for more than doubling the wilderness acreage of the National Park System and for the creation of Golden Gate National Recreation Area (Lang 2004).

The Point Reyes area is remarkable for the variety and significance of its geology. Here California's dramatic plate tectonic history is displayed. Most of the rock types associated with the Mesozoic collision between the Farallon Plate (now subducted and replaced by the Pacific Plate) and the North American Plate occur in this part of the Bay Area (Sloan 2006). Also the world famous San Andreas Fault reveals itself here, creating a wide valley that separates the Point Reyes peninsula from the "mainland." At the national seashore, Tomales Bay and Bolinas Lagoon mark the north and south ends of the fault zone respectively. West of the fault, the massive granitic Salinian Block of Point Reyes rides the Pacific Plate. East of the fault, the North American

Plate hosts the Franciscan Complex of the rest of Marin County. The Franciscan rocks—chert, serpentine, graywacke, and conglomerate—of the Marin mainland and Golden Gate National Recreation Area do not exist west of the San Andreas Fault.

Though synonymous with the San Andreas Fault in the minds of introductory geology students, the actual plate boundary between the Pacific and North American plates is a very broad zone of faulting and movement that includes the San Andreas, San Gregorio, and Golden Gate faults. Locally the zone is about 2.4 km (1.5 mi) wide but spans more than 160 km (100 mi) in other areas of California.

About 30 million years ago, the Point Reyes peninsula was adjacent to the Monterey Bay area; that is south of its present location by about 145 km (90 mi). The San Andreas Fault shows no pre-Oligocene (before 33.9 million years ago) offset. Since then the peninsula has crawled northward at an average rate of about 5 cm (2 in) per year. Some of this movement has been slow, intermittent, barely detectable "creep;" other has been in leaps and bounds, as when the peninsula moved as much as 6 m (20 ft) during the 1906 San Francisco Earthquake. Near the Bear Valley Visitor Center at Point Reyes National Seashore, the National Park Service maintains a trail along the fault zone. Blue posts mark the 1906 ground rupture, and a reconstructed fence shows the 5.5-m- (18-ft-) offset created during the quake.

Geologic Mapping for Point Reyes National Seashore

During the scoping meeting, Tim Connors (Geologic Resources Division) showed some of the main features of the GRE Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRE Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, a Windows HelpFile that captures ancillary map data, and a map document that displays the map and provides a tool to directly access the HelpFile. Final data products are posted at http://science.nature.nps.gov/nrdata/. The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm.

When possible, the GRE Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands. Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data (table 1) or develop a plan to obtain new mapping, if necessary.

Table 1. Source Maps for Point Reyes National Seashore

GMAP ID	Reference	GRE appraisal
2621	Clark, J. C., and E. E. Brabb. 1997. *Geology of Point Reyes National Seashore and vicinity, California: A digital database*. Scale 1:48,000. Open-File Report OF-97-456. Reston, VA: U.S. Geological Survey.	2008-0625: mostly use for PORE, but some applicability for northern GOGA. GRE has digital GIS files from USGS Web site. Need to compare/contrast with new Napa 100k (GMAP 74823) for best available data. PORE staff mentioned during scoping this data was smaller-scale than they ultimately desired, but not sure of anything published is larger scale
74823	Wagner, D. L., C. I. Gutierrez, and K. B. Clahan. 2006. *Geologic map of the south half of the Napa 30' × 60' quadrangle, California*. Scale 1:100,000. Sacramento, CA: California Geological Survey.	2008-0116: have PDF version from CGS; need to compare/contrast to other GMAPs for best data; also GIS files

Notes: CGS = California Geological Survey
GMAP numbers are identification codes for the GRE Program's database
GOGA = Golden Gate National Recreation Area
PORE = Point Reyes National Seashore

Point Reyes National Seashore has fourteen 7.5-minute quadrangles of interest: Valley Ford, Bodega Head, Point Reyes NE, Tomales, San Geronimo, Inverness, Drakes Bay, Drakes Bay OE W, San Rafael, Bolinas, Double Point, Drakes Bay OE S, Drakes Bay OE SW, and Farallon Islands (fig. 1). GRE staff plans to convert digital geologic data from the U.S. Geological Survey (i.e., GMAP 2621) to cover the park boundary. GRE staff will examine a newer publication by the California Geological Survey for the Napa 30' ×60' sheet (GMAP 74823) to see where it may enhance the final digital product. If possible, GRE staff will "edge match" the maps for Point Reyes National Seashore and Golden Gate National Recreation Area. Additional data include lidar that covers a 1-km-wide swath along the San Andreas Fault, which should be incorporated into the national seashore's geologic map. These data are available from the U.S. Geological Survey.

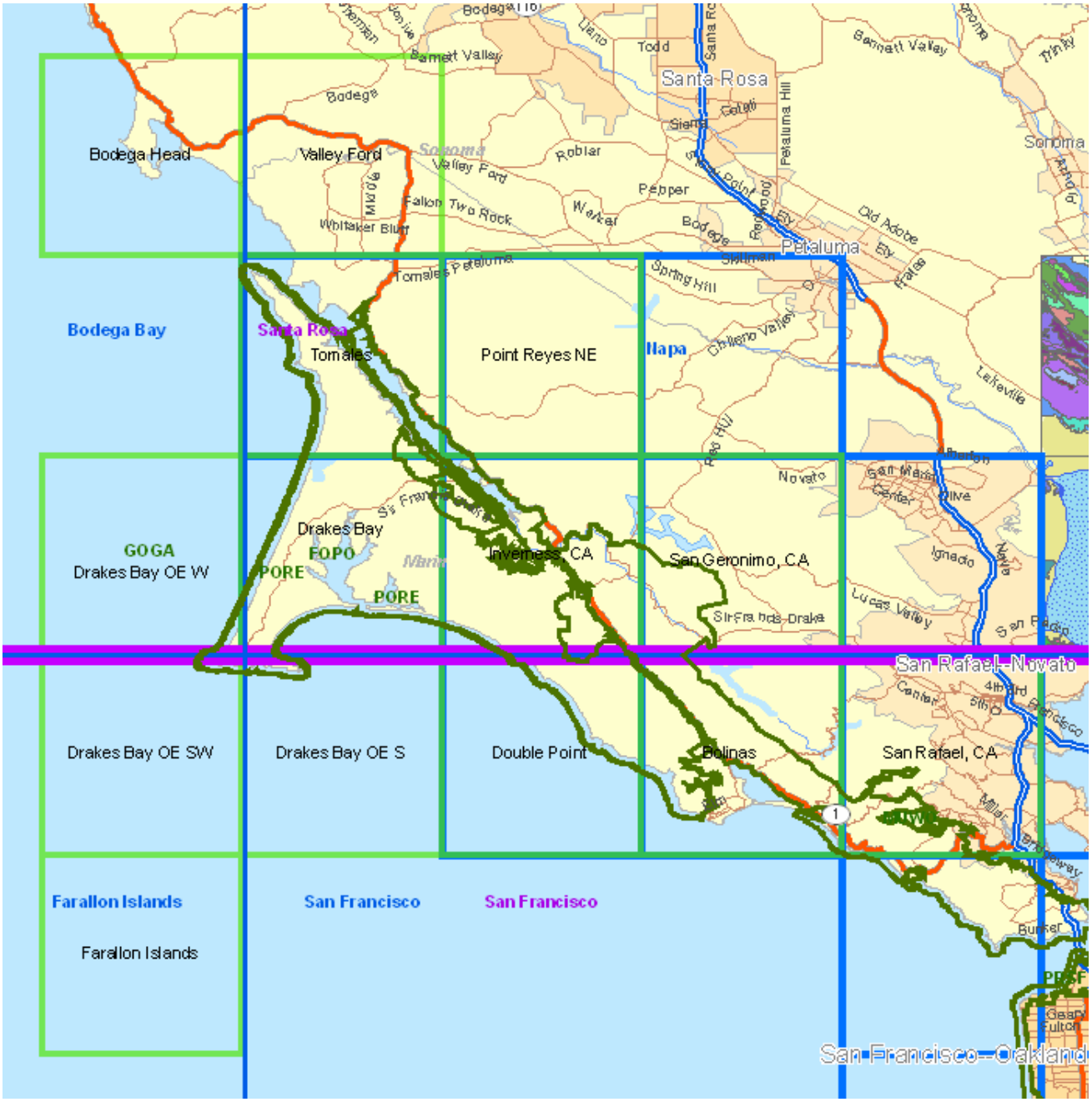

Figure 1. Area of Interest for Point Reyes National Seashore. The 7.5-minute quadrangles are labeled in black and outlined in green; 1:100,000-scale maps / 30' × 60' quadrangles are labeled in blue; 1:250,000-scale maps / 1° × 2° quadrangles are labeled in purple. The dark green outline indicates the national seashore's boundary.

During scoping, Russ Graymer (U.S. Geological Survey) mentioned that geology of the entire Bay Area is available digitally at 1:62,500 scale; however, park staff would like more refined surficial geologic mapping (>1:48,000 scale). The California Geological Survey has completed a compilation of earlier work for the Point Reyes area but not new 1:24,000-scale surficial mapping like that for other parts of the Napa 30' × 60' sheet (Chris Wills, California Geological Survey, e-mail to Bruce Heise, July 2, 2008). As of August 1, 2008, GRE staff had not devised a plan for how to provide large-scale surficial data to park staff but would entertain a proposal from the California Geological Survey (Tim Connors, Geologic Resources Division, personal communication, August 1, 2008).

Further discussion of mapping offshore geology occurred on September 28 (see "Coastal and Marine Features and Processes" section). Additionally, participants thought including seismic stations and locations of paleontological resource as GIS layers would be useful for park management (see "Seismic Features and Processes" and "Paleontological Resources" sections).

Geologic Features and Processes and Related Management Issues

The scoping session for Point Reyes National Seashore provided an opportunity to develop a list of geologic features, processes, and related management issues, which will be further explained in the final GRE report. Participants did not prioritize these issues, but discussion made it clear that coastal/marine and seismic features and processes have the greatest management significance. These are discussed first, followed alphabetically by other features and processes at the national seashore.

Coastal and Marine Features and Processes

As Gary Davis pointed out during the scoping meeting, "Everything in parks is protected…except fish." Visitors cannot take a pinecone, but commercial fishing takes 8 million tons of squid every year from Channel Islands National Park. This example illustrates the lack of attention that the National Park Service and the public have given marine resources. However, the tide is turning and the National Park Service has significantly advanced marine protection efforts through a number of initiatives in recent years, for example creating the Ocean and Coastal Resources Branch. Because of the voluminous yet unknown nature of the coastal and marine resources at Point Reyes National Seashore, the National Park Service held a "special session" with many invited participants as part of GRE scoping. Participants spent much of the time discussing a geologic map of the coastal and submerged portions of the national seashore. The California Geological Survey is now producing onshore-offshore geology maps, which may serve as a model for future mapping (e.g., Niven et al. [2008]). Participants suggested that a "gap analysis" be conducted to compile available data and consider various technologies for completing a digital geologic map for Point Reyes National Seashore.

Coastal and marine features and processes will be part of the final GRE report that accompanies the digital geologic map. Related issues that require management attention will also be highlighted. The "map units" will be a driving force for what features will be discussed in the report; however, participants began to outline many of the features, processes, and issues that should be included. Some of the features that participants discussed appear elsewhere in this scoping summary (e.g., sea caves are discussed in "Cave Features and Processes," and bluff failure and cliff erosion are discussed in "Hillslope Features and Processes"). Participants also identified a number of cultural resources that are affected by marine and coastal processes: Native American middens, paleo-fill material, lighthouses, and ship wrecks.

Features

- Beaches and spits
- Bluffs and cliffs
- Esteros
- Estuaries

- Headlands, including sea arches and stacks
- Inlets
- Islands
- Lagoons
- Rocky intertidal zone
- Submerged bathymetric features (e.g., bed forms and channels)
- Surf zone
- Tide pools

Processes

- Currents and their effects, including longshore and cross shore sediment transport
- Freshwater stratification, freshwater discharge, and freshwater plumes
- Groundwater discharge (submarine)
- Runoff
- Storm activity
- Tides and their effects
- Tsunami inundation, erosion, and deposition
- Upwelling (e.g., plume off Point Reyes and major retention zone on southeast side of the point at Drakes Bay)
- Wave action

Issues

- Aquaculture
- Flotsam and jetsam, especially land-based debris and refuse that accumulates in "trash collection areas"
- Invasive species that stabilize submarine features and change habitats
- Nutrient loading and harmful algal blooms, also potential dead (anoxic) zones
- Pollution: non-point source pollution (e.g., agriculture, septic systems, mines, and roads), pollutant discharges from vessels, contaminant transport and oil spills, sewage transport boxes, storm-water outfalls, and toxic waste dumps
- Reef burial
- Shipping-related issues: wakes, wrecks, grounding, and enormous submerged rocks
- Shoreline stabilization and development: fill, beach replenishment, piers, seawalls (buried and emergent), levees, roads, coastal fortifications, anthropogenic dunes on beaches, constructed lagoons, dolphins (free standing pilings), and rip-rap
- Saltwater intrusion into freshwater sources

Seismic Features and Processes

The national seashore's plate tectonic setting is world renowned. The landscapes of other National Park System units such as Channel Islands National Park, Pinnacles National Monument, and Golden Gate National Recreation Area are products of the setting where the Pacific Plate moves north-northwest past the North American Plate, but nowhere else is this setting more dramatic than at Point Reyes National Seashore. The large-scale surface expression of the plate boundary may be best appreciated from the air, but any map will reveal the distinctive, triangular-shaped wedge of the Point Reyes peninsula that exemplifies plate tectonics. Though it is only one of numerous faults in the broad transform boundary between the North American and Pacific plates, the San Andreas Fault is the "star" of the setting, perhaps because in recent times the San Andreas has taken up the bulk of the motion between the two plates (Lillie 2005). The San Gregorio Fault also runs through in the national seashore but is primarily offshore, which may be why it receives less attention. However, both faults are drivers of ecosystems. For instance, watersheds are shaped by fault processes. Repeated movement along faults has rearranged stream drainage, created sag ponds, and

crumpled up shutter ridges. At Point Reyes, seismic processes have created the unusual circumstance of two creek drainages—Pine Gulch and Olema—separated by only 3 m (10 ft) running parallel to each other but in opposite directions.

Historic accounts and photos of the 1906 earthquake, particularly those by USGS geologist G. K. Gilbert, informed modern-day, scientific thinking. Although softened with time now, the 1906 surface rupture was a conspicuous tear that continued for hundreds of miles across the landscape from San Juan Bautista in central California north to Cape Mendocino. The California Geological Survey and cooperators study paleoseismology along the San Andreas Fault at a work site just outside the boundaries of the national seashore. At this site, scientists have identified the slip rate and as many as 10 prehistoric quakes along the fault. Most of what is known about the San Andreas Fault has come from this site. Additionally numerous seismic stations are in the vicinity of Point Reyes National Seashore. Scoping participants suggested that seismic stations be a GIS layer for use in park management and interpretation.

Currently seismic activity is "quiet" at the national seashore as the fault appears to be locked and waiting for the next large quake. The probability of a large quake happening in the next 30 years on the San Andreas Fault is low; the probability is much higher for the Hayward Fault. Management concerns for the next large quake concentrate on roads: Would park managers be prepared to assist all visitors if a debilitating quake occurred on a weekend? Disaster scenarios consider damage to the Golden Gate Bridge, which would affect Point Reyes National Seashore and Golden Gate National Recreation Area. Both parks have emergency response plans in place.

Geologic hazards associated with earthquakes include ground shaking and strong ground motion, liquefaction, and fault displacement. The California Geological Survey is a source of information for these hazards. Additionally tsunamis are an earthquake-related hazard. The 1906 earthquake generated a tsunami (Geist and Zoback 1999). Roger Byrne at the University of California–Berkeley has age dates of tsunami deposits in Bolinas Lagoon that are on the scale of hundreds of years old (Byrne 2006).

Cave Features and Processes

Sea caves—clefts or cavities at the base of sea cliffs—occur at the land-water interface at Point Reyes National Seashore. Generally wave action enlarges sea caves along natural lines of weakness in weathered rock. Because these caves are at sea level, tides may also affect them. Scoping participants admitted a nearly complete lack of knowledge of sea caves as a natural and recreational resource at the national seashore, though sea lions are known to inhabit them. The caves are accessible by kayak, and some are accessible by land at low tide. As such they may be part of a "water trail" system. Bruce Rogers, a USGS geologist, has informally inventoried some of the caves on his personal time. A first step toward an official inventory and study of sea caves would be to consult with Rogers and potentially compile his field notes. The local National Speleological Society (NSS) grotto may be interested in assisting with field work.

Climatic Change

Losing Ground: Western National Parks Endangered by Climate Disruption states, "A climate disrupted by human activities poses such sweeping threats to the scenery, natural and cultural resources, and wildlife of the West's national parks that it dwarfs all previous risks to these American treasures" (Saunders et al. 2006). The authors contend that "a disrupted climate is the single greatest threat to ever face western national parks." Because of the potential disruption that climate change could cause to park resources, including geologic features and processes, the GRE Program has begun to include a discussion of the effects of climate change on park resources as part of scoping. Participants at the scoping meeting for Point Reyes National Seashore identified the following as possible outcomes of climate change: (1) sea-level rise; (2) habitat changes and loss; (3) more severe storms; (4) accelerated run off, sedimentation, and landslides; (5) increased temperatures; and (6) changes in hydrologic regime and fire patterns. An action plan for responding to

climate change will be part of the national seashore's general management plan, which as of September 2007 was in draft stages.

According to Rus Graymer (U.S. Geological Survey), Point Reyes is being uplifted at a rate of 1 mm (0.04 in) per year. The question remains whether uplift will beat sea-level rise at Point Reyes. Investigators estimate that sea-level rise is 2.51 ± 1.27 mm per year at Point Reyes (Zervas 2001). These numbers foreshadow a bleak outlook for terrestrial, nearshore resources at the national seashore.

Disturbed Lands

Modern human activities have disturbed more than 127,480 ha (315,000 ac) in 195 National Park System units. Some of these features may be of historical significance, but most are not in keeping with the mandates of the National Park Service. Disturbed lands are those park lands where the natural conditions and processes have been directly impacted by mining activities, development (e.g., facilities, roads, dams, abandoned campgrounds, and user trails), agricultural practices (e.g., farming, grazing, timber harvest, and abandoned irrigation ditches), overuse, or inappropriate use. Usually, lands disturbed by natural phenomena such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires are not considered for restoration unless influenced by human activities.

Restoration activities return the quality and quantity of an area, watershed, or landscape to some previous condition, often some desirable historic baseline. To accelerate site recovery, restoration at disturbed areas directly treats the disturbance and aims to permanently resolve the disturbance and its effects. For more information about disturbed lands restoration, contact Dave Steensen (Geologic Resources Division) at dave_steensen@nps.gov or 303-969-2014.

Point Reyes—The Enchanted Shore romanticizes the Point Reyes peninsula as a place where visitors can "leave modern California and enter an island of wilderness, forgotten by progress, a quiet land misplaced in a noisy world" (Timble 1980). Though the national seashore and wilderness area obviously retain much natural character, scoping participants pointed out that "there are no areas that haven't been disturbed" by military (e.g., an airstrip), grazing, agricultural and dairy farming, logging, and aborted urban development (i.e., Drakes Beach Estates). Mining has also impacted the area. Point Reyes National Seashore has more than 30 borrow pits, as well as historic lime kilns. Park managers have administratively closed the borrow pits and have plans to restore them. Soil erosion and runoff from the abandoned Gambonini Mine—a 5-ha (12-ac) site on a steep hillside that drains to Salmon Creek, a tributary of Walker Creek on the north side of Tomales Bay—was sending as much as 82 kg (180 lbs) of mercury per year into the creek and bay as recently as 1999 (http://yosemite.epa.gov/opa/admpress.nsf/a21708abb48b5a9785257359003f0231/03a9d3fb34dee6de852570d8005e17c7!OpenDocument). Though the Marin Conservation Corps, U.S. Environmental Protection Agency, and San Francisco Regional Water Quality Control Board conducted a six-year cleanup and restoration project at the site, scoping participants contend that mercury still remains in the floodplain sediments of Walker Creek. No oil and gas activities are occurring at Point Reyes National Seashore, though past exploration is marked by some dry wells.

Eolian Features and Processes

Point Reyes Beach—19 km (12 mi) of crashing waves and shifting sands—lines the seaward edge of Point Reyes National Seashore. The beach sands are derived from nearby bluffs composed of Merced Formation, which is highly erodible. Where sea cliffs are low, the sand drifts inland to form dunes, which provide shelter from the almost ceaseless winds (Sloan 2006). Water and wind move the sand on and off the beach with the seasons and drive it southward by longshore drift to the Point Reyes headland, where it is trapped. The beaches at Point Reyes National Seashore have both active (climbing) and inactive (paleo) dunes. Some paleo-dunes occur on ridge tops. The inactive dunes are not lithified. Park managers treat most dunes as unique habitats; some host endangered species (e.g., San Francisco lessingia [*Lessingia germanorum* Cham.],

a shrubby aster). According to a USGS report, coastal-dune habitat at Point Reyes supports 11 federally listed species, including the threatened western snowy plover (*Charadrius alexandrinus nivosus*) and endangered plants such as Tidestrom's lupine (*Lupinus tidestromii*) and beach layia (*Layia carnosa*) (Dingler and Anima 2007). Dunes also contain fossil pollen, which may be a source of paleoclimate data.

Many dunes are anchored by nonnative plant species. Park managers are trying to eliminate one such species, European beachgrass (*Ammophila arenaria* (L.) Link). By creating an armored dune system, this species is altering natural processes (e.g., washover and sediment deposition) and changing geomorphic features (e.g., spits). Another management concern is organic enrichment of dunes, which can change the entire character of these features. Also landscaping, including plantings and hard structures, as well as roads and larger structures can block wind and cause sand starvation in localized areas.

Fluvial Features and Processes

Flooding is a concern for park management. Maximum flows occur during and immediately after winter storms. Most runoff occurs during the 50 to 70 days of winter storms. Steep basins and shallow soils promote rapid runoff and "flashy" storm flow. After the last significant rain of the season (around April), streamflow steadily declines. Dry season baseflow is low, and flow ceases in some streams in the summer (National Park Service 1990). Where flooding occurs downstream of park lands, external owners want the National Park Service to "take action." In places, infrastructure exacerbates flooding damage, for instance at poorly engineered culverts and where channels are armored; it also impedes natural streamflow. Much of the infrastructure in the floodplains (e.g., pre-1960s stream crossings, dams, and roads) is poised to fail. Enhanced incision is largely related to past land-use practices, which have dramatically changed flooding conditions and floodplain morphology. Changes in natural flooding regimes are resulting in the invasion of exotic species in riparian areas.

Nearly 25% of the lands in Point Reyes National Seashore are "pastoral" and leased to private operators through agricultural special use permits. Seven dairies, one riding stable, and a number of beef cattle ranches are operated under such lease agreements (Ketcham 2001). The leases occur within some of the most sensitive watersheds, including Drakes Estero, Limantour Estero, Abbotts Lagoon, Olema Creek, Pine Gulch Creek, and Tomales Bay (Ketcham 2001). Grazing, agriculture, and recreational use of the waters at Point Reyes National Seashore, and the increased sedimentation and pollution that they cause, pose a substantial threat to resources such as aquatic habitats that support threatened and endangered species, including coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), and the California red-legged frog (*Rana aurora draytonii*) (Ketcham 1999, 2001). Several restoration projects are in progress for watersheds and wetlands at the national seashore (e.g., the Giacomini wetland restoration project), and park managers are trying to educate landowners and influence public perception about the sustainable use of floodplains.

Geothermal Features and Processes

Deep faults (see "Seismicity" section) provide conduits for geothermal waters. For instance, the Palomarin area at the national seashore hosts sulfur seeps.

Hillslope Features and Processes

According to Chris Wills (California Geological Survey), the landslides shown on bedrock maps are often less than 20% of the actual coverage. In general, USGS bedrock geologists intentionally do not include landslide deposits on their maps. They only include them if the deposit is massive and obscures bedrock. This is not to say, however, that landsliding is not a significant process at Point Reyes, rather that such deposits are not often mapped with any degree of accuracy. Hillslope features and processes at Point Reyes include debris flows, submarine and coastal landslides, bluff failures and erosion, undercutting, and the influx of upland sediment into the coastal sediment budget. Park managers have solid, historical documentation of debris flows and incision during flooding events.

Gravity-driven processes are a particular management concern on popular beaches with high visitation. The following safety warning is posted on the national seashore's Web site (http://www.nps.gov/pore/planyourvisit/yoursafety.htm):

> Cliffs and Rockfalls—Many of the cliffs and bluffs found within Point Reyes National Seashore are composed of friable rocks and are quite unstable. Rockfalls and slumps occur regularly, so visitors should stay several meters away from the edge of clifftops and the base of the cliffs. Because of the crumbly nature of the rocks, rock climbing within Point Reyes National Seashore is discouraged.

Lacustrine Features and Processes

The lakes at Point Reyes National Seashore have seismic and mass-wasting origins. Depressions behind landslide deposits gradually fill with water, becoming freshwater lakes (and wetlands) that serve as prime habitat for snakes and birds and hunting grounds for predatory mammals. Additionally sag ponds form where recent fault movement impounds stream drainage. These are classic lacustrine features of the San Andreas Fault. A curious question for resource managers at the national seashore is how to manage the "mobile habitat" that these lakes provide.

Farmers and ranchers created a hundred or more stock ponds in the national seashore by damming streams. These now serve as habitat for frog populations.

The waters at Point Reyes are also important recreational resources and provide opportunities for birding, swimming, kayaking, and canoeing, and serve as hiking destinations. The February 23, 1997, edition of the *San Francisco Chronicle* named Bass Lake as the number one place in the Bay Area to go swimming (Ketcham 1999).

Paleontological Resources

Will Elder (Golden Gate National Recreation Area) conducted an inventory and conditions assessment of the paleontological resources for the entire San Francisco Bay Area Network. According to Elder, who presented information during scoping, "fossils are huge" at Point Reyes National Seashore. The Point Reyes Conglomerate (Eocene) contains plant material such as fossil seeds, planktonic foraminifera, and some small marine invertebrates. Perhaps the most "charismatic" fossil of the Monterey Shale (Miocene) is fossil whales, but this formation also contains diatoms, foraminifera, crabs, and echinoids. The Purisima Formation (Miocene–Pliocene siltstone and mudstone) hosts marine mammals such as fossil walrus and shark remains, primarily teeth. The soft Merced Formation (Pliocene–Pleistocene) contains many cetaceans such as whales. Will Elder estimates that 100 baleen whale fossils are exposed in the sea cliffs at Point Reyes. The Pleistocene Millerton Formation—in the terraces of Tomales Bay—and the organic-rich sand and gravel of the Olema Creek Formation (Pleistocene) contain fossil fauna and flora (e.g., terrestrial plants).

Park managers would like to have paleontological locations as part of their GIS but do not want this layer served over the Internet. Wright (1974) may provide data for this layer.

Unique Geologic Resources

Unique geologic resources may include natural features mentioned in a unit's enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, and geologic features worthy of interpretation. The GRE Program also considers type localities and age dates as unique geologic resources. At Point Reyes National Seashore, unique features include the type sections for the following formations: Merced Formation, Point Reyes Conglomerate, Millerton Formation, and the Olema Creek Formation.

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